

MECHANICAL ENGINEERING
(Paper II)

Time Allowed : Three Hours

Maximum Marks : 300

QUESTION PAPER SPECIFIC INSTRUCTIONS

(Please read each of the following instructions carefully before attempting questions)

There are EIGHT questions divided in two Sections.

Candidate has to attempt FIVE questions in all.

Question Nos. 1 and 5 are compulsory and out of the remaining, any THREE are to be attempted choosing at least ONE question from each Section.

The number of marks carried by a question/part is indicated against it.

Wherever any assumptions are made for answering a question, they must be clearly indicated.

Word limit in questions, wherever specified, should be adhered to.

SECTION 'A'

1. Answer any three of the following:

- (a) Define 'Availability' with regard to a system. What is the other term by which this property is also referred to? Also derive an expression for "A" (the availability) for a reversible cycle in which heat 'Q' is withdrawn. The cycle works between temperatures T and T_0 . **20**
- (b) Describe briefly one-dimensional isentropic flow. Represent isentropic compression (diffusers) and expansion (nozzles) processes in a Temperature (T) – Entropy (S) coordinate diagram with nomenclature. **20**
- (c) Draw the Meridional view of a single stage axial flow fan and a multistage axial flow compressor. Describe an axial flow fan with its flow configuration. **20**
- (d) The thermal conductivity of a hollow sphere of inside radius (R_i) and outside radius (R_o) is given by

$$K = K_i + (K_o - K_i) \left(\frac{T - T_i}{T_o - T_i} \right)$$

where, T_i = Inner surface temperature, T_o = Outside surface temperature. Prove that (i) The heat flow rate is given by

$$Q = 4\pi R_i R_o \left(\frac{K_i + K_o}{2} \right) \left(\frac{T_i - T_o}{R_o - R_i} \right).$$

(ii) Also determine the heat loss from a spherical shell whose $D_i = 2.5\text{ m}$ and covered with 30 cm of insulation. The thermal conductivity of insulation is 0.3 W/mK and 0.2 W/mK at inner and outer surface temperatures of 150° C and -15° C respectively. **20**

- 2. (a) Derive equations for the change in internal energy and entropy of a gas which obeys the van der Waals equation of state. **15**
- (b) Define the Joule – Thomson coefficient and prove that for an ideal gas, the value of Joule – Thomson coefficient tends to zero. **10**
- (c) 2 kg of air is first compressed from state 1 at 13.75 N/cm^2 and 5° C to state 2 at 48 N/cm^2 and 283° C. It is then throttled to state 3 until its pressure is again 13.75 N/cm^2 . Finally it is cooled at constant pressure to state 4 until its volume becomes 50% of that before the cooling process. Determine the net change in entropy. ($R = 0.291\text{ N.m/g.K}$; $C_p = 1.004\text{ kJ/kg.K}$) **20**

- (d) Write a short note on Redlich – Kwong equation of state. **15**
3. (a) Derive an expression for the Mach number after a normal shock wave occurring in a nozzle. Show the trend of this Mach number, (in the form of an x-y plot) with respect to the Mach number value before the shock. **15**
- (b) Air enters a diffuser with a velocity of 250 m/s and a temperature of 30° C. It leaves with a velocity of 90 m/s. Neglecting friction and heat transfer determine (i) exit temperature (ii) exit pressure if the inlet pressure is 125 kPa and (iii) area ratio between the exit and entrance. Will your answers change if there is friction present? Explain how. **30**
- (c) For a circular tube, explain with the help of neat sketches (i) Hydrodynamic entry region and hydrodynamically developed flows. (ii) Thermal entry region and thermally developed flows. **15**
4. (a) An oil is cooled to 100° C in a parallel flow heat exchanger by transferring its heat to cooling water, that leaves the exchanger at 30° C. However, it is now required that the oil must be cooled down to 75° C by increasing the length of heat exchanger, while oil and water flow rates, their inlet temperatures and other dimensions of the exchanger keeping constant. The inlet temperatures of water and oil are 15° C and 150° C respectively. If the original cooler was 1 metre long, determine (i) outlet temperature of water in the new cooler and (ii) length of the new cooler. **30**
- (b) A hot plate of 15 cm^2 area maintained at a temperature of 200° C is exposed to still air at 30° C temperature. When the smaller side of the plate is held vertical, convective heat transfer rate is 14% higher than when the bigger side of the plate is held vertical. Determine the dimensions of the plate. Neglect internal temperature gradient of the plate thickness. Also determine the heat transfer rates in both the cases. Use the following relation: $Nu = 0.59 (Gr \cdot Pr)^{0.25}$ Take the following properties of air: **30**

Temperature (°C)	$\rho \text{ (kg/m}^3\text{)}$	$C_p \text{ (kJ/kg-K)}$	$\mu \text{ (N-s/m}^2\text{)}$	$K \text{ (W/m-K)}$
30	1.165	1.005	18.6×10^{-6}	0.0267
115	0.910	1.009	22.65×10^{-6}	0.0331
200	0.746	1.026	26×10^{-6}	0.0393

SECTION 'B'

5. Answer any three of the following:
- (a) Draw a schematic of a pass-out turbine and explain its working. Represent the relevant process on Enthalpy – Entropy coordinates. **20**
- (b) How is the heat balance of a CI engine often diagrammatically represented by means of the following? (i) Pie chart (ii) Bar chart (iii) Sankey diagram (iv) Graph with x-axis as power output in percentage and y-axis as total heat input in percentage. **20**
- (c) In what way is Velox boiler different from La Mont boiler? Describe the working of the Velox boiler with a schematic. **20**
- (d) What are the components to be considered for estimating (i) cooling load, (ii) heating load for an air-conditioning system? How do you calculate heat gain through ducts for an air-conditioning system? **20**
6. (a) (i) Briefly explain 'Evaporative Cooling System' which is generally used for big-capacity stationary IC engines, with a schematic diagram. (ii) List four advantages and disadvantages each of a water-cooled system in a CI engine. **20**
- (b) Draw a schematic of a Benson boiler and explain its working principle, pointing out its speciality. **2**

- (c) Explain supersaturated flow in steam nozzles with the help of skeleton Mollier diagram inserting nomenclatures like dry saturated line, Wilson line and supersaturated zone. List also the five effects of supersaturation in the steam nozzles. **20**

7. (a) With the help of schematic and T – s diagrams explain a reheating Rankine cycle. State its advantages over ordinary Rankine cycle and define the reheat factor. **20**

- (b) Draw a schematic diagram of bubbling bed fluidized boiler and explain its working. **15**

- (c) The following observations refer to a surface condenser: Mass flow rate of condensate = 20 kg/min; Mass flow rate of cooling water = 800 kg/min; Mean temperature of condensation = 35° C; Condenser vacuum = 0.95 kg/cm²; Barometer reading = 1.03 kg/cm²; Inlet cooling water temperature = 20° C; Outlet cooling water temperature = 30° C; Temperature of the hot well = 29° C. Calculate: (i) Weight of air per unit volume of condenser. (ii) Entering condition of steam to the condenser. (iii) Vacuum efficiency of the condenser. Properties of saturated steam: **25**

T (°C)	P (MPa)	Sp. Vol. (m ³ /kg) v _f	Sp. Vol. (m ³ /kg) v _g	Enthalpy (kJ/kg) h _f	Enthalpy (kJ/kg) h _g	Entropy (kJ/kg.K) S _f	Entropy (kJ/kg.K) S _g
35	0.0056	0.001	25.245	146.56	2565.4	0.5049	8.3543

(Use $R=0.287 \text{ kJ/kg.K}$)

8. (a) The outdoor summer condition for a Bank for one hundred persons is $T_{db}=310 \text{ K}$, and $T_{wb}=300 \text{ K}$. The required inside conditions are $T_{db}=295 \text{ K}$ and $\phi=60\%$. The room sensible heat is 4,00,000 kJ/hr. The room latent heat is 2,00,000 kJ/hr. Ventilation requirement per person is 0.0047 m³/hr. The By-pass factor is 0.15. Evaluate: (i) Grand total heat (ii) Effective sensible heat factor (ESHF) (iii) Apparatus dew point (iv) Volume flow rate of dehumidified air **40**

- (b) 20 m³ of air per minute at 30° C DBT and 60% RH is sensibly cooled to 22° C DBT. Take saturation pressure of water vapour at 30° C and 22° C temperatures to be 0.425 bar and 0.0265 bar respectively. Find heat removed from air. Take atmospheric air pressure $p_b=1 \text{ bar}$. **20**
